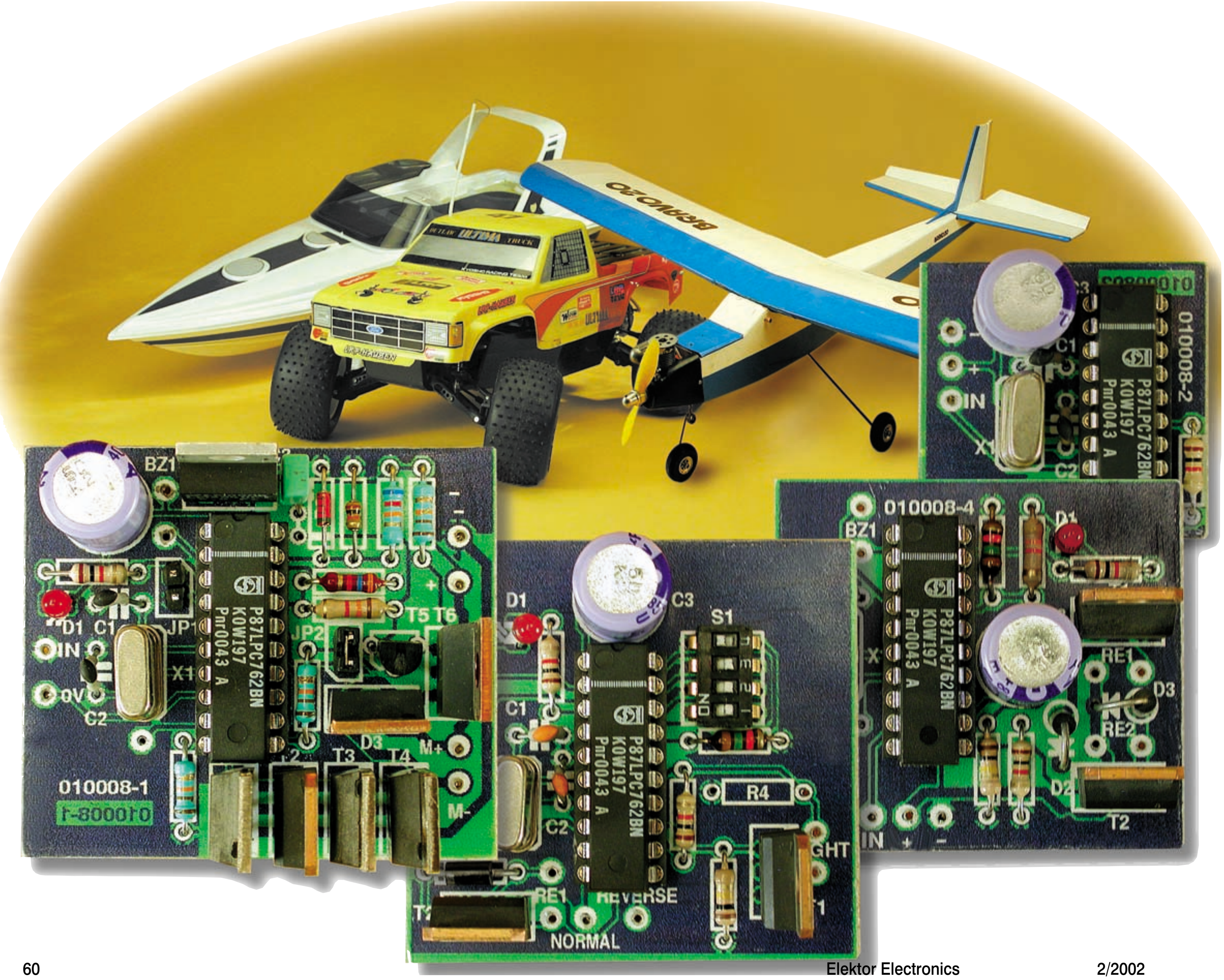
Multi-purpose IC for modellers (1)

Fourteen functions using four PCBs

Here is something the modelling world has never seen before: a single chip that can be fitted to four different PCBs and which offers 14 functions which can be combined in various configurations as if it were a standard component. This unique device is a readily available microcontroller, and it derives its versatility from the software with which it is programmed.



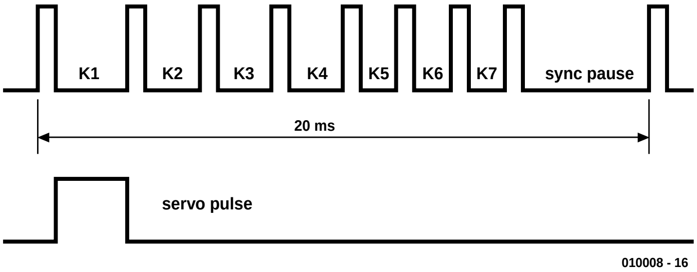


Figure 1. Typical PPM signal.

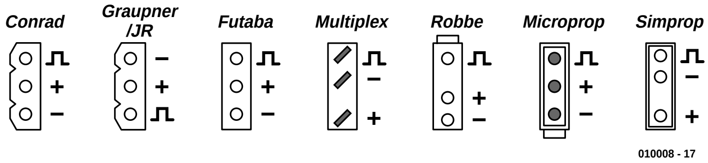


Figure 2. Pinouts of the commonest types of servo connectors.

Table 1

Function summary:

- Model finder (a buzzer is activated when the transmitted signal is absent or severely distorted)
- Receiver voltage monitoring with indicator
- Motor voltage monitoring with indicator
- 2-channel switch
- Hot glow (switches on glow plug when motor is idling)
- Servo filter
- Anti-collision lights
- Soft start
- Speed control
- Fail-safe system
- Servo reverse
- Y-cable replacement
- Servo balancing
- Go-slow (reduces servo speed)

Model builders continuously demand more and more functions from their systems, which can be implemented either by using expensive computerised transmitters or by adding auxiliary circuits at the receiver end. These circuits are almost always designed for one specific function, with the result that often more hardware is used than strictly necessary. In models where weight is critical this can mean that some of the additional functions have to be sacrificed. Also, there is always only a limited amount of space at the receiver end for circuit boards, and the less electronic hardware there is in the model, the more reliable the whole system. Moreover, by implementing as many different functions as possible in a microcontroller, the user can select just those required for his particular application.

Since it makes little sense to implement all the functions on a single circuit board, four different variants have been developed, which can be populated as the user wishes. A socket is recommended for the microcontroller, so that it can be moved as necessary from one board to another. The system employs a 'universal chip' which provides all the most frequently required functions. An overview of the individual functions of the multipurpose device (which is based on a Philips microcontroller type 87LPC762) appears in **Table 1**.

How these functions can be combined will be explained later.

SERVO CONTROL

Before we look at the functions and circuits in detail, a few words on the fundamentals of servo control in models.

Modern radio control systems use either PCM (pulse code modulation) or PPM (pulse position modulation). In a PCM system the position of each joystick and switch on the transmitter is converted into a value in the range 1 to 255.

These digital values are sent out from the transmitter one after another as 8 bit quantities. Along with the control information so-called 'check bits' are included in the PCM signal. With the aid of these check bits the microcontroller in the receiver can verify the correctness of the incoming data stream and so ensure that only reasonable commands are sent to the servos.

If an erroneous signal is detected, the servos retain the most recently received correct settings until a new code is correctly received. PCM systems thus offer particularly reliable data transfer. Partly because of the limited bandwidth and the large quantity of data to be transmitted, the repetition rate of the transmitted commands is lower than with conventional PPM systems. One must always bear in mind that the radio signal undergoes analogue processing before the software in the microcontroller has a chance to process it digitally. A distorted signal, which is beyond the PCM system software's capability to analyse, may well be adequate for a PPM system to provide limited control of a model. So a PCM-based system will either work correctly — or not at all. There is no middle ground.

In a PPM system a series of narrow pulses is transmitted, see **Figure 1**. The positions of the

Table 2

Characteristics of the 87LPC762 microcontroller

- Operating voltage 2.7 V to 6.0 V
- Instruction cycle time 300 ns to 600 ns at 20 MHz
- RAM: 128 Bytes
- ROM: 2 or 4 kbyte (87LPC764)
- 2 timers
- 2 analogue comparators with built-in 1.23 V reference
- Full-duplex UART
- I^2C communications port
- 2 external and 8 keypad interrupts
- Watchdog with separate oscillator
- On-chip power-on reset
- Low-voltage reset
- Internal RC oscillator without external components or quartz crystal oscillator with capacitors
- Programmable port configuration (quasi-bidirectional)
- Open drain
- Push-pull
- Input only
- Serial programming facility
- Idle and power-down modes

joystick and switches are represented by the time intervals between the pulses. The time interval corresponding to a joystick setting can vary between 0.9 and 2 ms. A complete transmitted frame for all channels occupies 20 ms. This means that the control commands are sent 50 times per second. The extra delay allows the decoder circuit in the receiver to synchronise to the next pulse packet.

As a rule servos are connected to the receiver via a three-conductor cable. The connections are power and ground, and a pulse signal whose length determines the servo arm position. Since there are various connector systems in existence with various pinouts, we have shown the commonest connection arrangements in **Figure 2**.

THE MICROCONTROLLER

The 87LPC762 device chosen belongs to a large family of microcontrollers based around an 80C51 core with a OTP (ROM) program memory between 2K and 4K in size. The 'LPC' in the part code indicates low power, low price and low pin count. The notable features of these controllers are their high processing speed and their integrated RC oscillator and reset circuit. The user thus has 18 I/O pins at his disposal. The main technical characteristics are given in **Table 2**.

A 6 MHz quartz crystal (X1), along with capacitors C1 and C2, is used for the microcontroller's clock. This gives an instruction cycle time of 1 ms. Further information, as well as the complete data sheet, can be found on the Internet at Philips' homepage at http://www.semiconductors.com/mcu/.

Servo filter function

The servo filter function of this multi-purpose IC can be combined with many of the other functions from Table 1. The main function is illustrated in **Figure 3**.

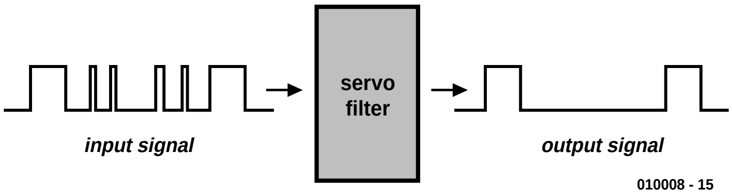


Figure 3. Action of the servo filter.

Receivers that process PPM signals pass on interference to the servos. Such interference manifests itself in spikes or in errors in the pulse lengths, making the servos either jitter or run out of control.

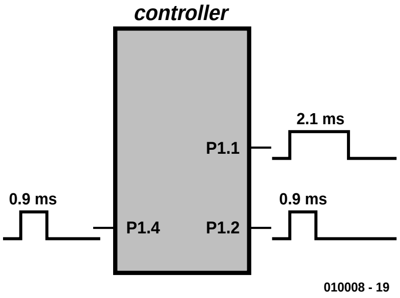


Figure 4. The principle of the servo reverse function.

The output signal of the receiver is first analysed by the microcontroller, before it is sent to the appropriate output or converted into some other action.

Incoming pulses must have a duration of between 769 ms and 2304 ms. After that, the controller waits for approximately 16 ms before starting to check the receiver signal again. The microcontroller now expects a valid signal within approximately the next 9 ms. Errors that occur are counted and when a preset value is reached, the 'fail safe program' is activated.

Because of this interference rejection function the output signal of the receiver must have a repetition rate of between 36 Hz and 57 Hz. Dropouts in the pulse of up to 40 ms in duration are ignored by the software. Also, the amplitude of the signal at the output of the receiver must be at least 0.6 V_{DD} to drive the Schmitt trigger input of the microcontroller. Spikes on long servo wires that do not reach this level will not be recognised. It is therefore recommended that if the servo connections are long (as on aircraft wings for example) the servo filter (i.e., the circuit board with the multi-purpose IC) be placed as near as possible to the servo. The result of all these precautions is a servo control signal practically free of interference and whose quality comes very close to that achieved in PCM systems.

SERVO REVERSE

Practically every modern radio control transmitter offers the facility to reverse the direction of the servo's motion. Why should this function not be incorporated into the multipurpose IC? There are at least two good reasons in favour: two servos can now be connected, and we can easily control a pair of ailerons using separate servos driven from the same channel. Secondly, sometimes a mirror-image servo is required to operate elevators individually. The reason for this is that the relationship between movement of the servo and that of the elevator can depend on where the servo is fitted.

Figure 4 shows the principle of the servo reverse function using the multi-purpose IC. The practical realisation appears in **Figure 5**. The printed circuit board shown in **Figure 6** has been developed for this application, which offers both the servo reverse function and the servo filter function. This printed circuit board (order code 010008-2 from Readers Services) also offers the third function of a replacement for a Y-cable, as long as the reverse sense of the motion of one of the servos is taken into account.

RECEIVER VOLTAGE MONITORING

An adequate supply voltage is vital in a remote controlled model. Continuous checking of the battery voltage is essential to guarantee safety for the spectators (and for the model!). For this reason this function is built in to three of the four application circuit boards for the device; only in the case of the servo reverse circuit board described above is it dispensed with, in the interests of compactness. The special feature of the voltage monitoring system employed here is that brief breaks in the supply are detected and permanently stored.

One of the two comparators in the microcontroller is dedicated to the voltage monitoring function (**Figure 8**). Using the internal 1.23 V ref-

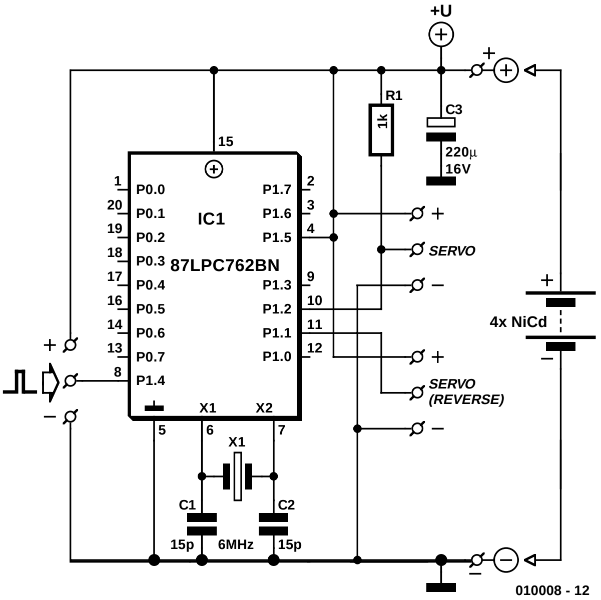


Figure 5. Circuit for the servo reverse function using the multi-purpose IC.

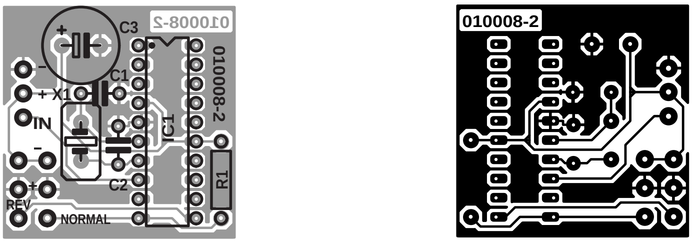


Figure 6. The printed circuit board for building the circuit of Figure 5 also offers the servo filter and Y-cable replacement functions.

COMPONENTS LIST

(PCB shown in Figure 6)
010008-2

Resistors:
R1 = 1kΩ

Capacitors:
C1,C2 = 15pF
C3 = 220µF 16V radial

Semiconductor:
IC1 = 87LPC762BN (programmed, order code **010008-41**)

Miscellaneous:
X1 = 6MHz quartz crystal
2 off servo cable with female connector
1 off servo cable with plug
PCB, order code **010008-2**

erence voltage and external resistors R4 and R5 allows the microcontroller to react when the voltage falls below 4.8 V: it turns on permanently the LED connected to port pin P1.6 (**Figure 8**), and alters the flash rate of the anti-collision lights featured on circuit board **010008-3**, to be described in the second instalment in this series. Once lit, the LED stays permanently on and can only be turned off when the microcontroller is reset and supplied with a voltage of at least 4.7 V. The LED will thus reliably indicate if the supply voltage has at any moment fallen below a safe level. This provides an early indication that the battery should be changed. The switching level for this function can be set as required by selecting suitable values of R4 and R5 in the potential divider. If resistors of the right value cannot be obtained, the desired voltage level can of course be set using a small potentiometer in the place of R4.

TWO-CHANNEL SWITCH

A few extra features can add that certain something to a remote controlled model. A firefloat, for example, might feature a working water pump; a rescue vehicle might feature lights or a horn; or an aeroplane might have landing lights. In many radio transmitters, one joystick channel is used for each switching function, using up a proportional channel. It is not exactly an economical use of the channel capacity to use a full proportional channel to transmit a simple on/off state. Using the multi-purpose IC in the circuit of **Figure 9** (with corresponding printed circuit board in **Figure 10**), moving the joystick in the positive direction operates one switch while moving it in the opposite direction operates another. The output state of the switch is latched: that is, the output state toggles on each activation and is held until the next one.

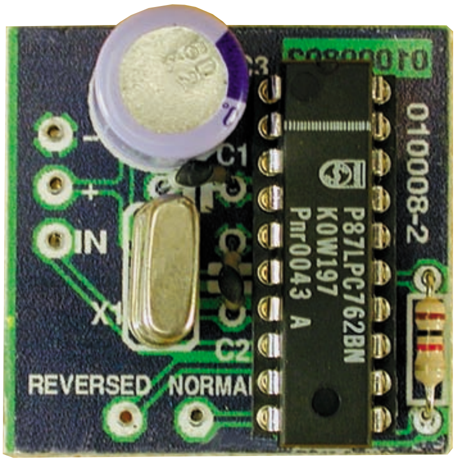


Figure 7. The populated servo reverse circuit board.

The power MOSFET for channel 2 is driven from microcontroller pin P1.0 and switches when the input pulse width is less than 1.2 ms. The FET for channel 1 is driven from pin P1.1 and switches when the input pulse width is greater than 1.8 ms. The MOSFETs used can switch currents of up to around 10 A without additional cooling and can operate at voltages of up to 55 V.

MODEL FINDER

Anyone who has ever made a forced landing in a cornfield will know how tedious it can be to find one's model again. Moving the joystick wildly to and fro in the hope of hearing the noise of the servos is only occasionally successful. Usually it is only possible to find the model by searching through the field system-

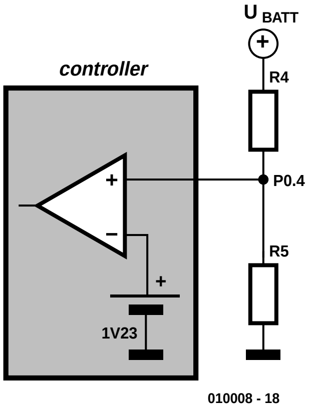


Figure 8. Internal comparator in the microcontroller.

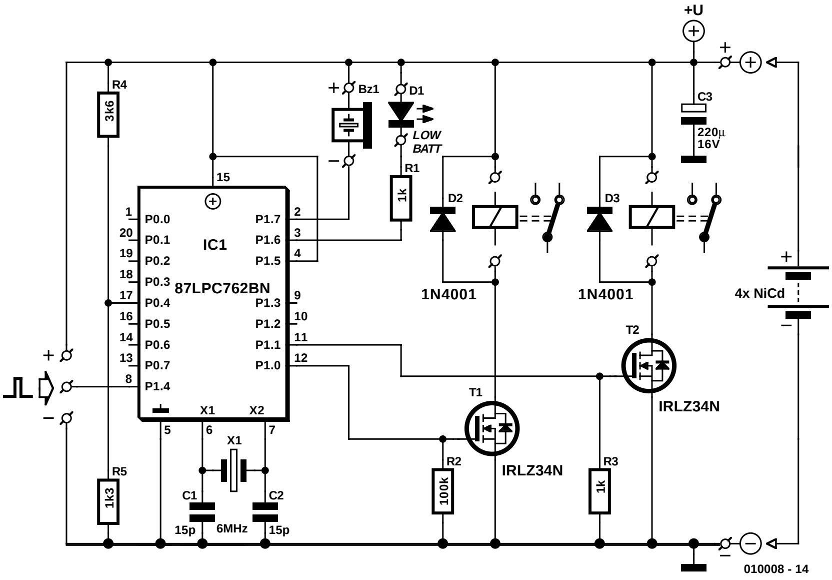


Figure 9. Circuit of the 2 channel switch board, also offering battery voltage monitoring and model finder functions.

atically — which doesn't always endear you to the farmer! The microcontroller provides on pin P1.7 an active low signal that can drive a buzzer (with built-in electronics) directly. The alarm is automatically activated after 2 seconds if the receiver does not provide a valid signal, either because the transmitter has been turned off or because the signal is severely distorted. This function is available on all the printed circuit boards except the servo reverse board. If this function is not required, the buzzer can be dispensed with.

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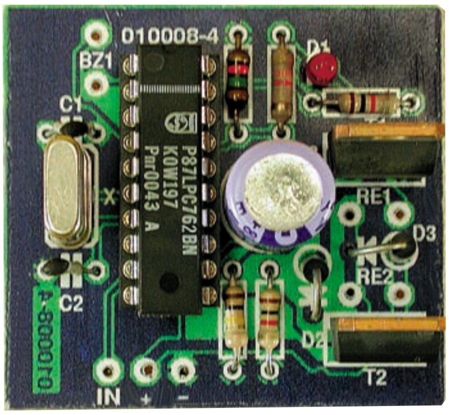

Figure 11. The populated 2 channel switch circuit board.

Web addresses

Microcontroller:

www.semiconductors.com/mcu/

N-channel MOSFET:

www.irf.com/product-info/datasheets/data/irlz34n.pdf

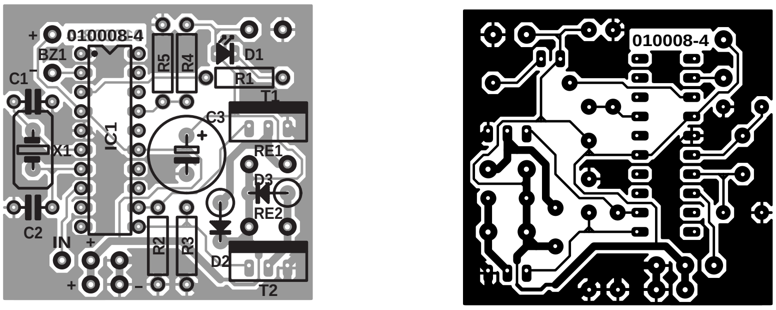

Figure 10. Printed circuit board for building the 2 channel switch.

In the next instalment we will present the two remaining circuit boards, offering speed control, soft start, motor voltage monitoring, BEC (battery elimination circuit), anti-collision lights, fail-safe system, 'hot glow', differential rudder control, and 'go-slow' functions.

COMPONENTS LIST
(PCB shown in Figure 10)
010008-4

Resistors:
R1,R3 = 1kΩ
R2 = 100kΩ
R4 = 3kΩ6
R5 = 1kΩ3

Capacitors:
C1,C2 = 15pF
C3 = 220µF 16V radial

Semiconductors:
D1 = LED, red, low-current
D2,D3 = 1N4001
IC1 = 87LPC762BN, programmed, order code **010008-41**
T1,T2 = BUZ71/IRLZ34N

Miscellaneous:
Bz1 = DC buzzer, 5V
X1 = 6MHz quartz crystal
1 off servo cable with plug
PCB, order code **010008-4**
Disk (source code file), order code **010008-11**